THE GERMINATION AND JUVENILE FORMS OF SOME OAKS

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THE GERMINATION AND JUVENILE FORMS OF SOME OAKS.

L. H. PAMMEL AND C. M. KING.

The question of how some of our oaks germinate and the fact that little has been recorded upon this subject has come to us on several occasions.

It is definitely known that the white oak germinates in the fall and the red oak in the spring. The bur-oak, according to the statement of a Minnesota correspondent, germinates in the fall. We have held the opinion that this oak, although not closely related to the red and black oaks, also germinates in the spring, an opinion recently verified by actual observation. This fact is undoubtedly due largely to its environmental conditions. the bur-oak occurring in situations that are somewhat dry. There is some difference of opinion regarding the germination of the English oak. The botanical authors in the Encyclopedia Brittannica[1] state that the acorns of this oak germinate in the spring. This is contrary to what we find to be true in the East-European form of the English oak, commonly known as the Russian oak (*Quercus Robur* var. *pedunculata*) which is grown on our college campus. The acorns of this oak germinate in the fall. In view of this lack of well established information, it seems timely to publish a few preliminary notes on the germination of some Iowa oaks.

Figures of germinating acorns of some oaks have been used to illustrate texts on Morphology; as the classic figure in Gray's Structural Botany[2] used by various authors and illustrations from Sach's and from Rossmässler in Marshall Ward's[3] treatise on the oak.

Dr. George Engelmann[4] made a study of the germination of the live oak (*Q. virginiana*), in which he records the development of little tubers, a fact well known to the negro children of the South, by whom they are eaten.

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[1] Encycl. Britt., *19*, 931 (11 Ed.). Also in the previous edition.

[2] Lessons in Botany, Gray (6 ed.), 20.

[3] The Oak, H. Marshall Ward, 20, 22.

[4] Botanical work of the late George Engelmann, edited by Gray and Trelease; also Trans. Acad. Sci. St. Louis 4, 408-410.

This led him to make a study of the germination in a number of species of oaks. He noted the fleshy cotyledons, the "little caulicle, and at the upper end, toward the center of the acorn, the two stalks or petioles of these cotyledons." The plumule is but slightly developed. These structures vary somewhat in different species. In the black oaks (*Q. nigra*), etc., he found that the stalks are longer than the caulicle. In *Q. macrocarpa, Q. Robur* and *Q. chrysolepis*, the caulicle is nearly three times as long as the stalk. In the majority of white oaks (*Q. alba, Q. stellata*), etc., the caulicle is shorter than the stalks of the cotyledons. The longer stalks are found in *Q. virginiana.* Sargent[5] gives the following general description of the germination of the acorn:

> The radicle is imbedded near the apex of the seed between the fleshy cotyledons with the minute plumule or growing point between thin petioles toward the middle of the seed; the radicle in the North American black oaks and in a few of the white oaks being longer than the petioles of the cotyledons, and shorter in most of the white oaks. In germination the petioles of the cotyledons with the plumule, lengthen pushing the plumule outside the cracked shell of the nut within which the cotyledons remain; the plumule develops into the ascending axis of the plant, which is covered in its lower nodes with minute scales, and is nourished by the food contained in the cotyledons, which rot and disappear toward the end of the first season after the radicle, by absorbing some of their nutritious material, has become swollen and enlarged.

That the cotyledon may furnish food supply for the second season, is stated by H. Marshall Ward:

> The two cotyledons remain inclosed in the coats of the acorn; the developing root obtains its food materials from the stores in the cells of the cotyledons, as do all the parts of the young seedling at this period. In fact these stores in the cotyledons contribute the support of the plant for many months, and even two years may elapse before they are entirely exhausted.

Sir John Lubbock[6] describes the germination of two European species, e. g. the *Q. Robur* var. *pedunculata* and *Q. Ilex.* These species are said to be very similar in their germination. Like all oaks the germination is hypogæous, the primary leaves are reduced to scales, and the hypocotyl soon becomes woody; the cauline leaves are alternate, stellately pubescent on both surfaces, the pubescence soon disappearing, distantly serrate in the seedling stage, nearly always entire in the adult tree; stipules linear, subulate.

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[5] The Silva of North America, 8, 2, 4.

[6] Contribution to our knowledge of seedlings, 534, London, 1892.

Dr. Englemann[7] notes that the young leaves of almost all oak seedlings are stellate pubescent, and that the trichomes of *Q. macrocarpa* and *Q. nigra,* and *Q. marylandica* have articulate hairs. C. K. Schneider[8] notes that the hairs should be called "Büschelhaare" instead of "Stern harre." The percentage of germination of the red oak is rather low. Richard H. Boerker[9] found in the case of red oaks that it requires fifty-four days for germination in gravel, forty-six days in sand; forty-two days in dense shade and eighteen days in medium shade.

The germination of acorns of this species in open light was 28 per cent; in medium shade, was 12 per cent; in dense shade 12 per cent.

In regard to soil, it was found that there was no germination in dry soil and medium wet soil; but in wet soil the germination was 28 per cent. In the case of soil texture he found germination in loam soil 28 per cent, in sand 24 per cent, in gravel 16 per cent. He found also that it required forty days for the germination to start.

In a study of the germination of the oaks we tried two methods; in one the acorns were placed in moist sphagnum moss and in the other in moist sandy humus in the greenhouse. Observations were made in the field also, though by examination of the ground under some trees it was found that in case of the red oak (*Quercus rubra*) up to May fifteenth none of the acorns had germinated. Some were covered up with earth, a yellow loam, and some were left lying openly on the ground. Only a very small number of the *Quercus Robur* var. *pedunculata* had produced any living plants in the spring. We also planted a considerable number of acorns of the following species on a yellow clay hill; *Quercus velutina, Q. alba, Q. rubra, Q. palustris, Q. imbricaria, Q. stellata,* and *Q. acuminata.* The gardener covered the acorns with ten inches of soil. On May 15 none of the acorns had germinated, but by June 15 a small percentage had germinated. The fact that so few of the acorns of the red oak covered with a little earth grew leads us to believe that germination is low in nature, except in very favorable seasons and conditions, at least so far as the red oak and other Iowa forms are concerned. In some years a considerable portion of the acorn crop is injured by species of Curculio.

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[7] Botanical works, etc., 391.

[8] Illustriertes Handbuch der Laubholzkunde, *1,* 161.

[9] Ecological Investigations upon the germination and early growth of forest trees. Doctor's thesis University of Nebraska, 1-89, *pl. 1-5,* 1916.

White oak (*Quercus alba* L.). The large acorns of the white oak occur abundantly and in nature may often be found germinating soon after they have fallen. A number of fresh acorns of this species were gathered on September 25 and planted on September 27 in the laboratory. They were kept moist in sphagnum moss. Another batch was planted in the greenhouse in sandy loam and kept moist with sphagnum. In a few days the acorns in both cases split at the apical end and sent out

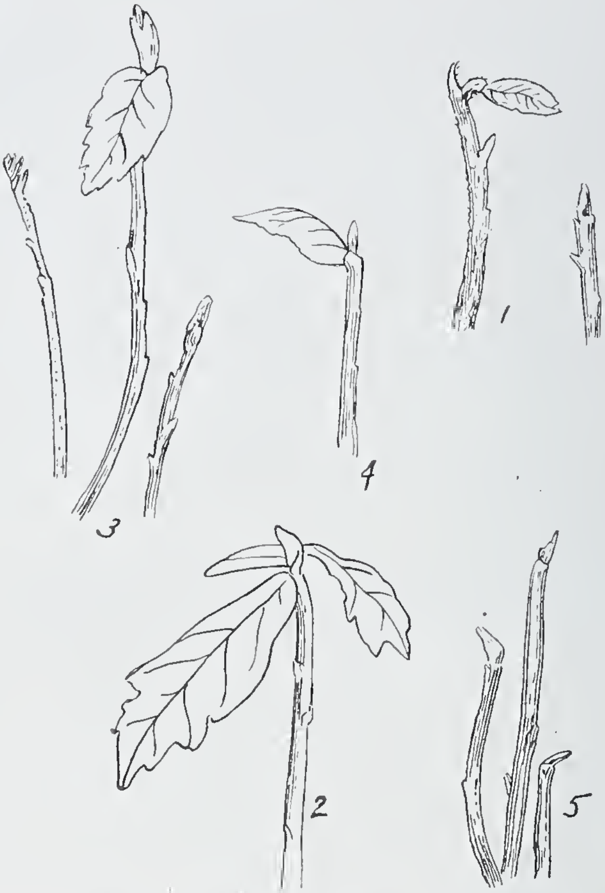

Fig. 58.—Young stem of white oak. Planted on October 8. 1, condition on October 25. 2, condition on October 31. 3 and 4, scales and young leaves. The leaves dropped off early in January. 5, condition in March. Drawn by C. M. King.

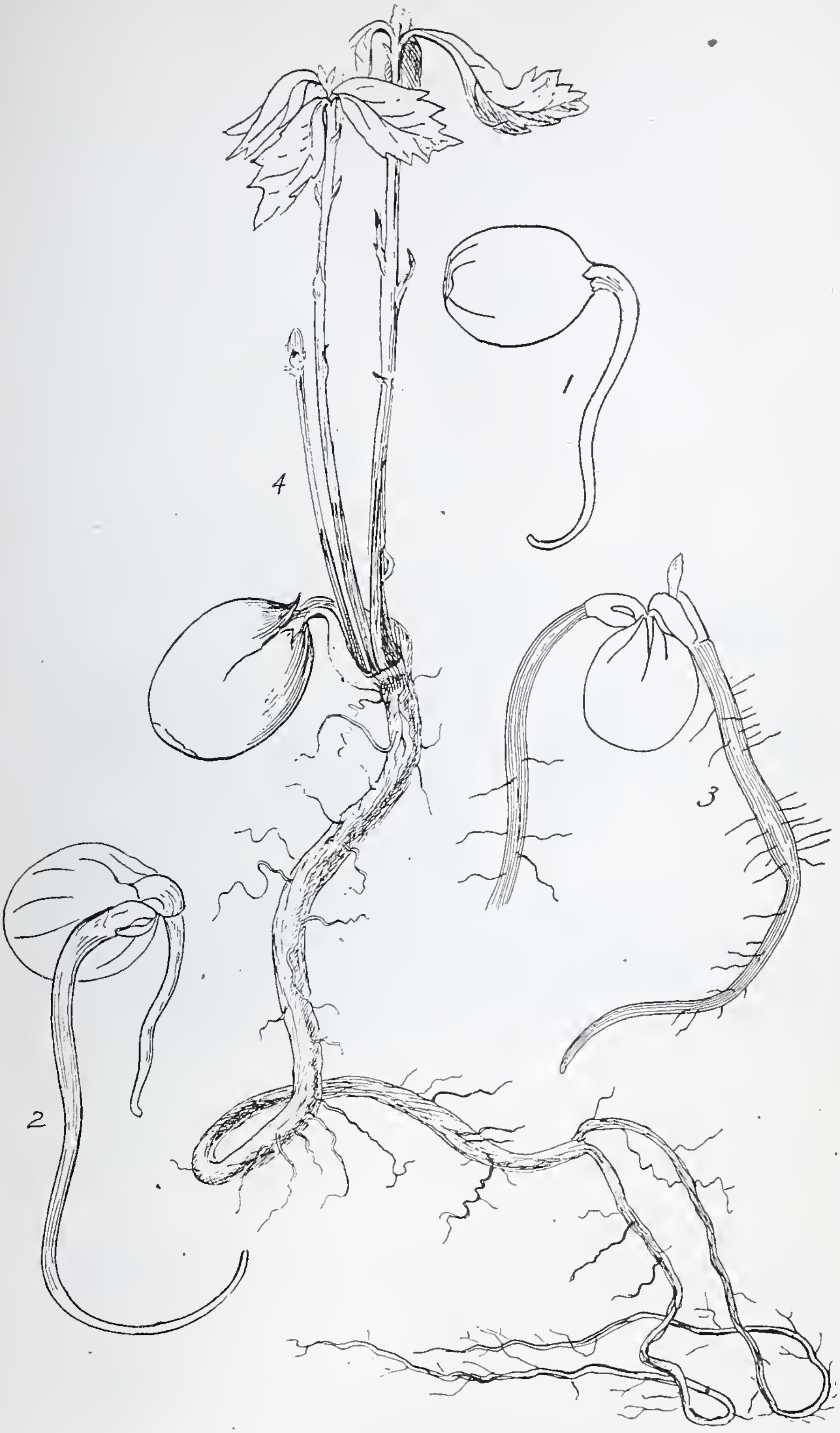

Fig. 59.—Germinating white oak, planted on October 10. 1, just beginning to germinate. 2, condition on October 25. 3, plumule partly ou and a second radicle and caulicle. 4, on November 14. Three stems produced, long root and a cuplike depression from which the three stems arise scales, stipules, and leaves also shown. Drawn by C. M. King.

the hypocotyl. The hypocotyl made a rapid growth; in five days it became somewhat woody and was more than twice as long as the acorn. Small lateral roots were soon produced. On November 14 the longest root measured 28 cm., while the longest stem measured 8 cm. The first leaves on the stem were reduced to scales, these scales successively increased in size; both scales and leaves were covered with trichomes. The trichomes of the stem are long pointed and frequently curved, generally occurring singly or sometimes in groups of two or three, not strictly stellate. Some trichomes woolly, especially on very young stems; the walls colorless, thick, contents brownish. On the green leaves trichomes simple, long pointed, thick walled, occasionally in clusters of two or three. Trichomes of upper surface similar to those on lower. On very young leaves the upper and lower surfaces are woolly, trichomes occurring singly or in groups. The first fully formed leaf was serrate In the greenhouse the

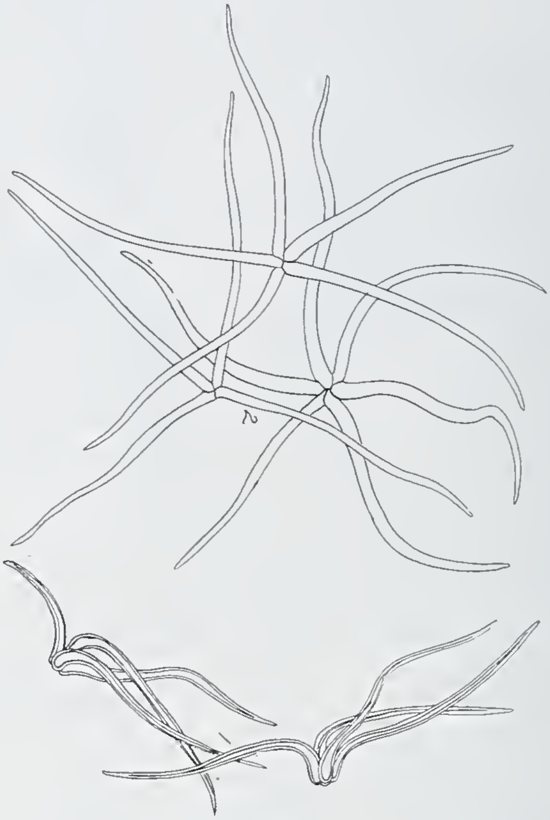

Fig. 60.—1. Trichomes of white oak from stem. 2. Trichomes of white oak from leaf. Drawn by C. M. King.

leaves dropped during the month of January and buds were formed. April tenth a new set of leaves appeared, the earlier ones were pinkish in color, drooping and covered with hair. One of the interesting features of the germinating white oak was that in many cases multiple stems come from between the short stalks of the cotyledons. It is well known that in white oak the stem is at first woolly, later becoming smooth. The white oak seems to have a higher percentage of germination than the red oak. A part of the higher germination for last season's crop was no doubt due to the less frequent attacks of insects. The total germination of the white oak at the close of the period was 73.6 per cent. On May tenth these seedlings ranged in height from three to four and one-half inches.

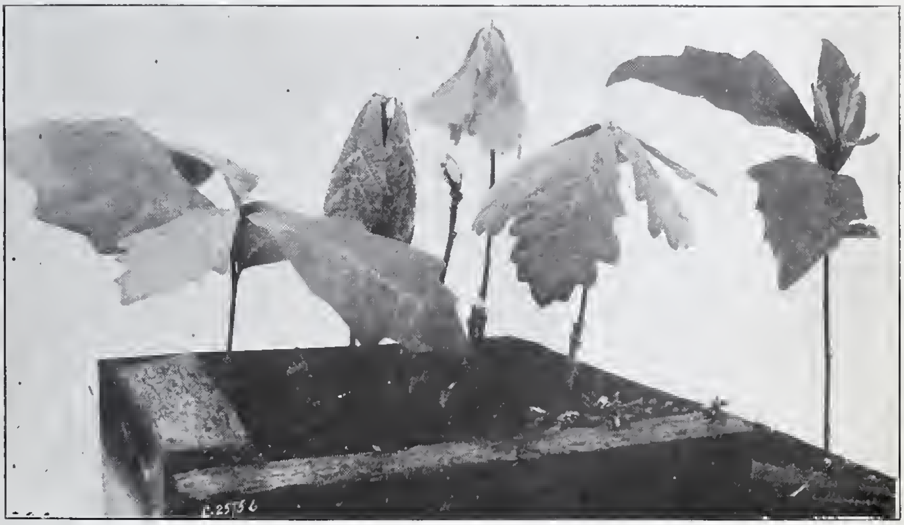

Fig. 61.—To the left young white oaks (*Quercus alba*) in greenhouse May, 1917. The central plant just unfolding. The ones to right, and left of this, a later stage with drooping leaves, the one on the left fully expanded. The one to the extreme right of figure is shingle oak (*Q. imbricaria*). Photographed May 1, by Colburn.

Chestnut Oak (*Quercus acuminata*) (Michx.) Hauba. The germination of the chestnut oak is hypogæous and the acorns germinate soon after falling from the tree. Acorns were gathered on September 25 and planted on the 27th in sandy humus in the greenhouse and covered with sphagnum; other acorns were placed in damp sphagnum moss. On October 8 many of these were split at the apical end. On October 25 the hypocotyl was more than five times as long as the acorn. The plumule made its way out near the upper end of the hypocotyl which at this stage was brownish and woody in texture, The first scalelike leaves on the stem were pubescent and alternately arranged. The young stem also was pubescent. The trichomes of the stem are long, slender and pointed, straight or curved, mostly single, walls white, contents brown. The trichomes of the leaves are like those on the stem, generally only one, though sometimes grouped in twos or threes, not strictly stellate. The later and upper leaves were penni-nerved and sharply dentate, the teeth becoming gradually larger toward the base, pubescent on upper and lower surface, scattered, simple, general form somewhat spatulate. The leaves below are glaucous. During the month of January the leaves dropped and the young twigs remained in this condition for eight weeks, when leaves again began to appear. The first leaves were penni-nerved, green on both sides, somewhat more shiny on the upper surface, pubescent on prominent veins and midribs, stipules soon falling. On May tenth these seedlings had reached a height of five to six inches.

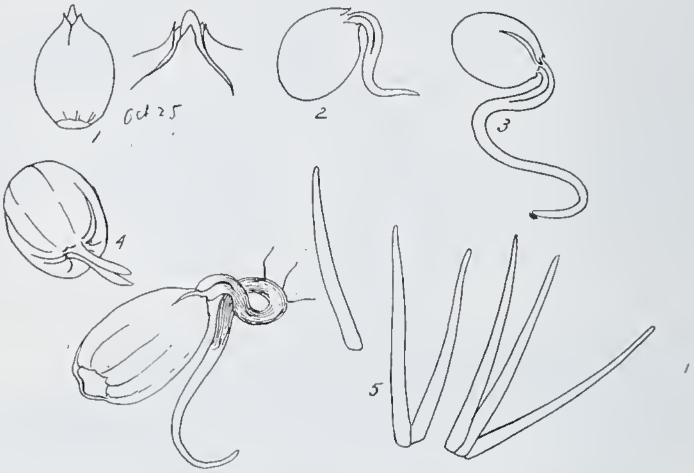

Fig. 62.—Germinating acorns of *Quercus acuminata*. 1. On October 25. 2. On November 7. 3. On November 13. 4. Twisted roots and young lateral roots. 5. Trichomes on stem. Drawn by C. M. King.

The acorns of this species germinate in about the same percentage that those of the white oak do. On April 13 the total germination was 75 per cent. There is probably little regermination in any of the oaks. When the hypocotyl and radicle do not penetrate the soil drying will destroy the plumule. We received from Mr. J. H. Frazier some acorns with the hypocotyl two inches long. These acorns were placed in damp sphagnum moss. No further growth could be observed. On opening the acorns in February the cotyledons in part were still fresh, but the portion next to the hypocotyl was decayed. The hypocotyl also had decayed.

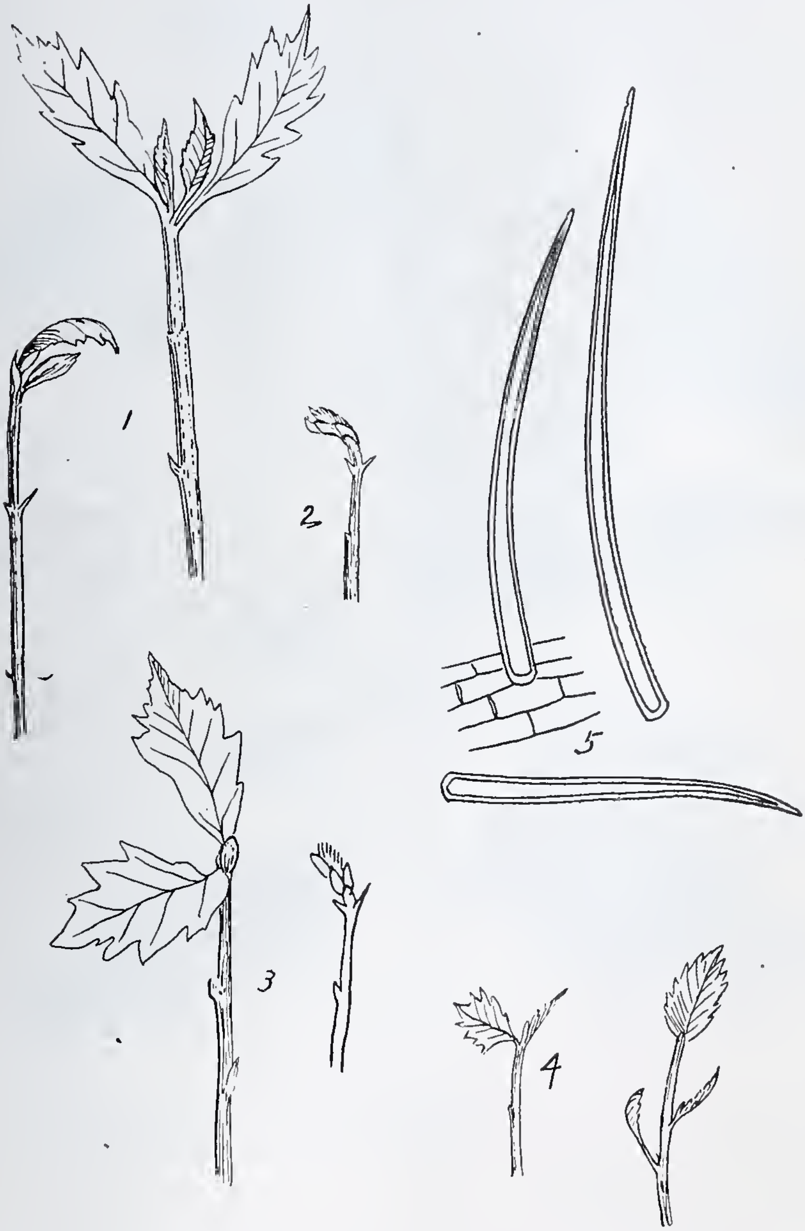

Fig. 63.—1. Germination of *Q. acuminata* acorns planted on October 8. 2, 3 and 4, condition on October 23 and 31. 5. Trichomes of stem. Drawn by C. M. King.

Valley Oak (*Quercus lobata* Nee.). Mr. George H. Kimball of Yuba City, California, sent in some fresh acorns of this species. They were planted early in October in sandy humus in the greenhouse, receiving an abundance of water. The surface was kept moist with sphagnum moss. In the course of a few days the acorns split near the upper apical end and the hypo-

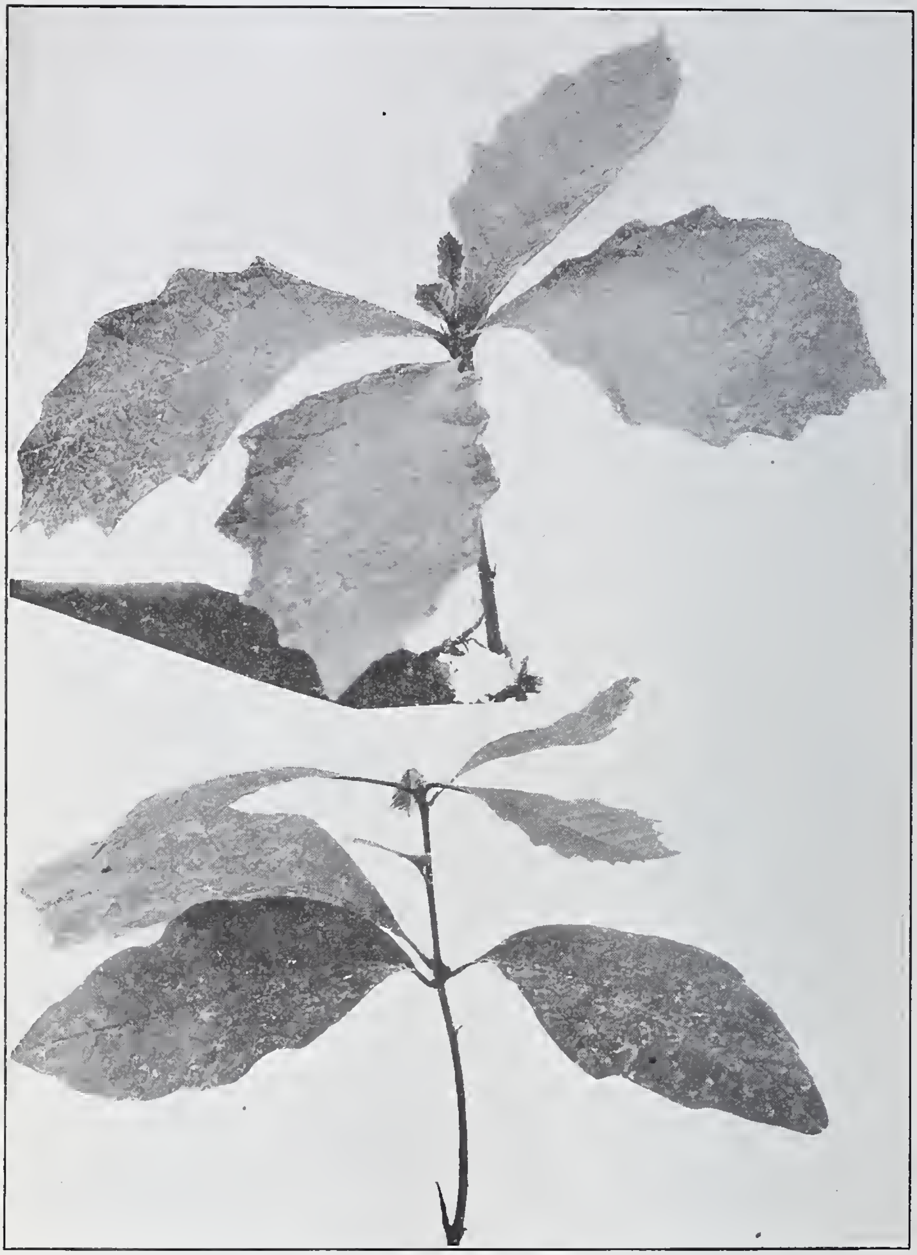

Fig. 64.—The upper figure seedling bur-oak with expanded leaves and very young leaves, stipules, also scales on stem. The lower figure chestnut oak (*Q. acuminata*), scales below on stem, full expanded leaves and unfolding leaves. Photographed May 1, by Colburn.

cotyl appeared. A single stem was produced that soon developed lateral branches. The stem was pubescent. The straight or slightly curved trichomes have a thick colorless wall and brown contents and occur generally singly. The lower leaves consist of scales. The upper leaves are larger penni-nerved with numerous teeth, with small points, the upper surface darker than the lower; the veins are light colored, prominent, mature leaves only slightly pubescent on the upper surface, especially on the midrib, lower surface of leaf pubescent with hairs on midrib and veins. Trichomes on lower surface of leaf mostly occur singly, sometimes two or three in a cluster, long pointed, straight or slightly curved, walls thick, colorless, contents brownish, the upper surface of leaf less pubescent than the lower. On May tenth these oak seedlings had reached a height of eighteen and one-half inches to twenty-two and one-half inches, a few smaller. The main root was twenty-four inches long.

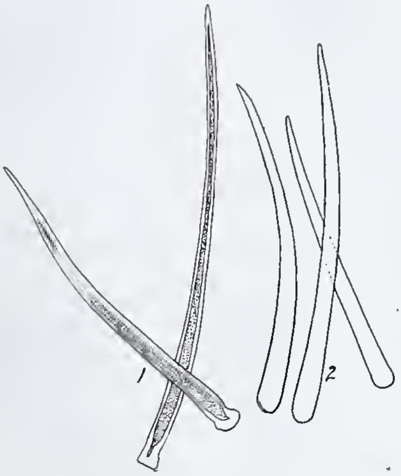

Fig 65.—Trichomes of valley oak (*Quercus lobata*); 1, from stem; 2, from leaf. Drawn by C. M. King.

George B. Sudworth[10] states that the species is a prolific seeder at intervals of about two years; reproduction exceedingly scanty because the tree grows on grass covered pasture or wheat land the surface of which is rarely broken when the seed falls. The seed germinates readily when well covered with fresh litter or soil, but it is seldom so covered by natural means.

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[10] Forest Trees of Pacific Slope; U. S. Dept. of Agr., Forest Service, 1908.

Russian Ooak (*Quercus Robur* var. *pedunculata*). The acorns were gathered on September 20, planted in the greenhouse in sandy humus, covered with sphagnum and kept moist. Many of the acorns were split at the apical end on October 4. The hypocotyl pushed its way down into the soil, increasing in length very rapidly. On October 18 it was two inches in length, at first whitish in color, becoming brownish.

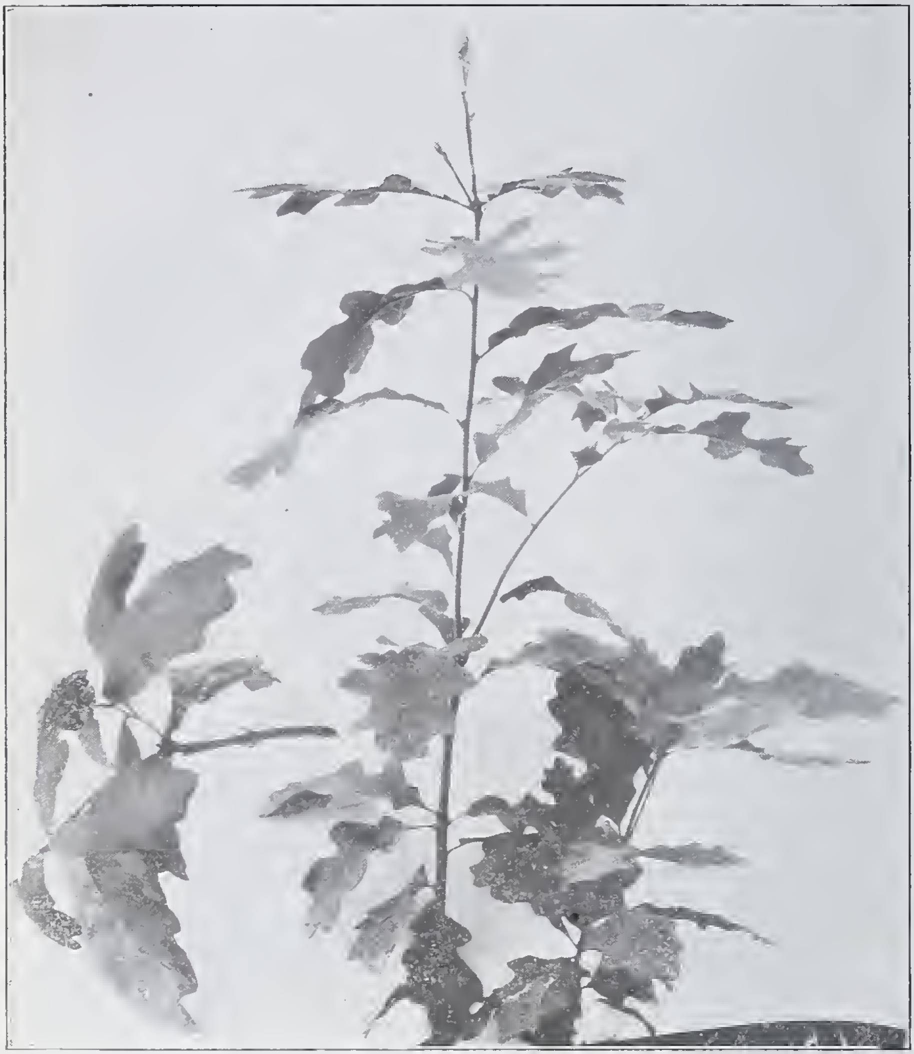

Fig. 66.—Right hand figure valley oak (*Quercus lobata*), fully expanded leaves and unfolding leaves, both branches from the same acorn. The left hand figure, Russian oak (*Q. Robur* var. *pedunculata*), showing stipules, scales and fully formed leaves. Photographed May 1, by Colburn.

Germination of *Q. Robur* var. *pedunculata,* according to observations of H. Marshall Ward,[11] occurs in the spring. Sooner or later as the temperature rises in the spring, the embryo in the acorn absorbs water and oxygen and swells, and the little radicle elongates and drives its tip through the ruptured investments at the thin end of the acorn and at once turns downward and forces itself slowly into the soil.

With us the acorn germinates abundantly in the fall soon after it falls to the ground, in September or October, varying with the season. In the greenhouse it tested 90 per cent germination. The plumule pushed out near the upper end, the young stem was slightly pubescent, the trichomes of the stem generally occurring singly, long pointed, straight or slightly curved, cell wall colorless, thick, contents brown, the lower leaves were scalelike, these successively larger, the fully formed penni-nerved leaves with margins of rounded teeth, upper surface of leaf shining, lower surface paler in color; midrib promi-

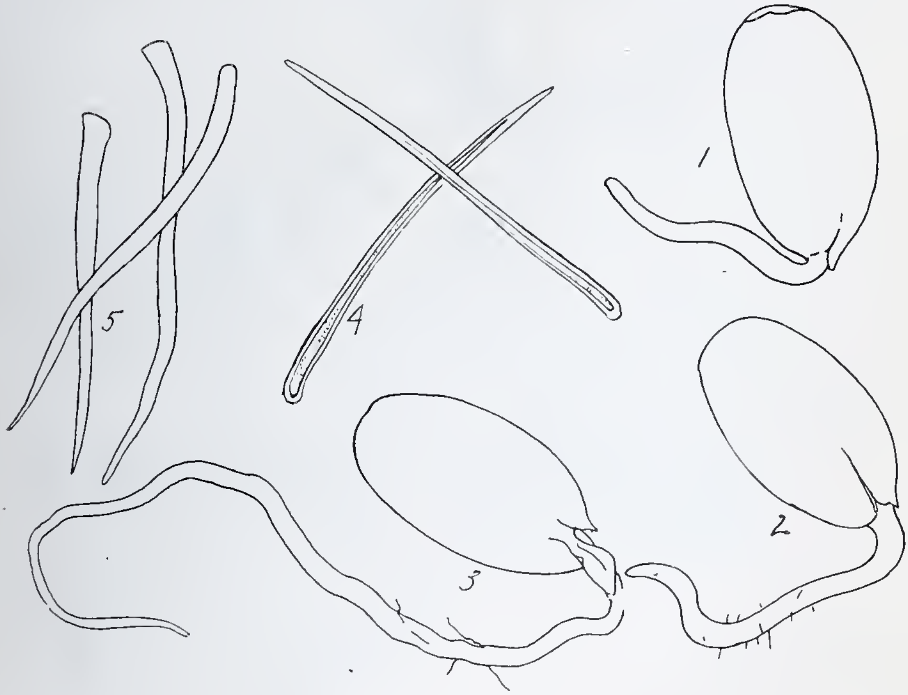

Fig. 67.—Germinating Russian oak (*Quercus Robur* var. *pedunculata*); 1, condition on October 4; 2, condition on October 20; 3, condition on October 30; 4, trichomes of stem; 5, trichomes of leaf. Drawn by C. M. King.

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[11] H. Marshall Ward, The Oak, 19.

nent, trichomes few on upper and lower surface of leaf, on very young leaves more numerous than when fully formed, singly or bunched, in some cases as many as five trichomes in a cluster, long pointed, cell walls thick, white, upper surface with similar trichomes, but less in number, either singly or from two to four cells in a group. By May 10 these oak seedlings were from four to seven inches in height, averaging three and one-fourth inches.

Post Oak (*Quercus stellata* Wang.). The acorns were sent to us from Johnson City, Tennessee, by J. H. Frazier. They were planted in the greenhouse on October 29 in sandy humus, covered with damp sphagnum. The germination is hypogæous and occurs soon after the acorns fall from the tree. The hypocotyl pushes its way through the acorn at the apical end. The hypocotyl is strong; it soon becomes thickened and is woody. On December 5 it was somewhat longer than the acorn. Growth was much slower than in the white oak. The plumule emerges near the basal end of the hypocotyl. The young stem is pubescent, trichomes occurring singly or in clusters of two, straight

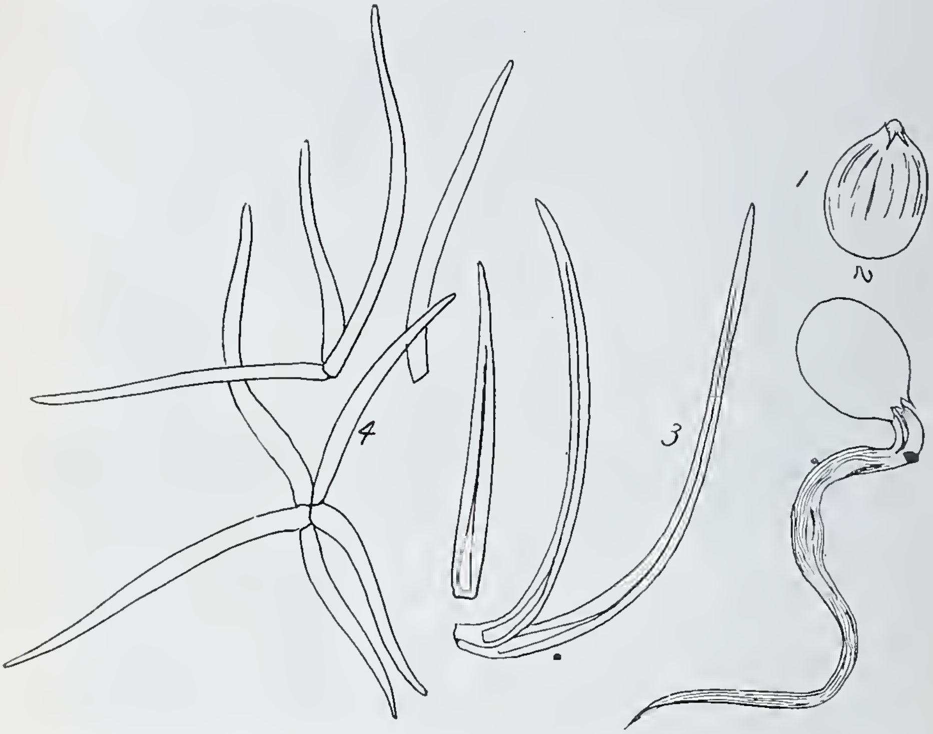

Fig. 68.—Germinating post oak (*Quercus stellata*), planted in October; 1, condition on November 10; 2, condition on December 5; 3, trichomes of stem; 4, trichomes of leaf. Drawn by C. M. King.

or slightly curved, variable in length, cell-wall white, thick, contents brown. The first leaves consist of scales, the upper larger, wide at the middle, with rounded lobes, pubescence scattered and abundant below, smooth above, trichomes on lower surface of the leaf. On May tenth seedlings of *Quercus stellata* were two inches in height.

Swamp White Oak (*Quercus platanoides* Lam.) Sudw. The acorns were gathered near Centerville, Iowa, on October 16. They were planted on sandy humus covered with sphagnum and kept moist. These acorns did not germinate until February. Lenticels are conspicuous on young branches, trichomes of stem long pointed, straight or slightly curved, walls thick, contents brown. The first leaves are somewhat pubescent. The leaves become successively larger, woolly pubescent, the upper leaves

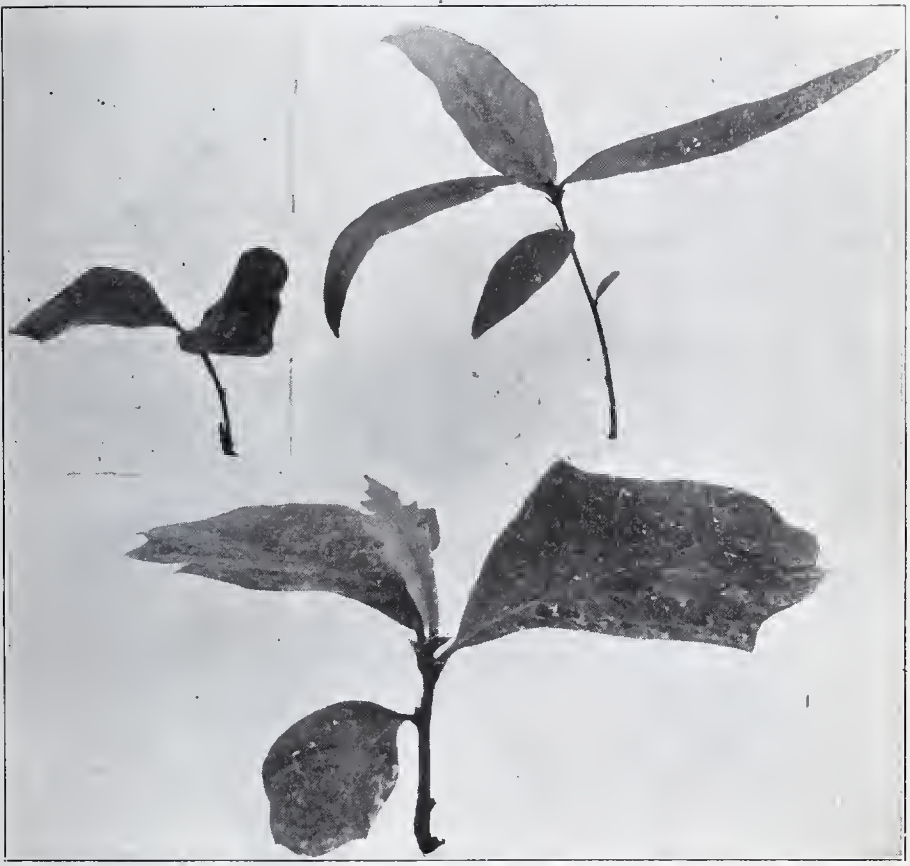

Fig. 69.—Upper left hand figure post oak (*Quercus stellata*). Upper right hand figure *Q. aquatica*, scalelike leaves on stem below, stipules and fully formed leaves. Middle figure *Q. velutina* with scales and stipules, younger and older leaves. Photographed May 1, by Colburn.

all penni-nerved, narrowed at the base, broader toward the middle, somewhat undulated, lower surface of leaf with scattered pubescence, persistent on the veins, scattered, occurring singly or in clusters of two or three, trichomes long pointed, straight or curved, cell walls thick, contents brown, upper surface with trichomes scattered and on midrib, singly or clustered, soon be-

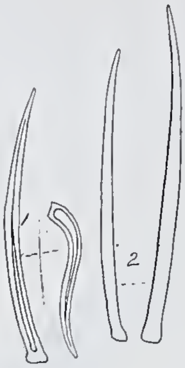

Fig. 70.—Trichomes from young plant of swamp white oak (*Quercus platanoides*); 1, from stem; 2, from leaf. Drawn by C. M. King.

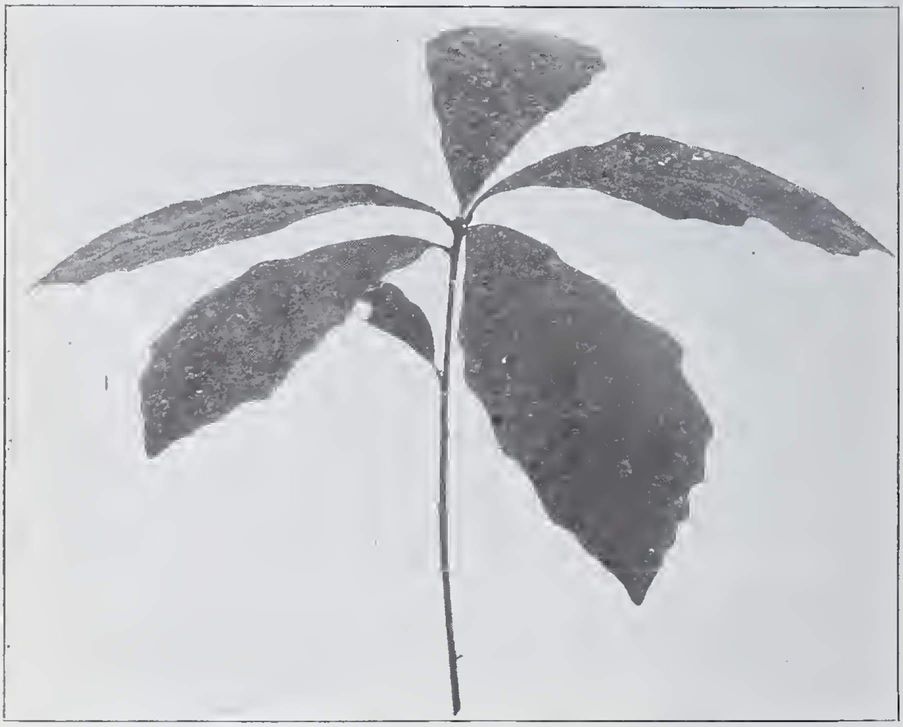

Fig. 71.—Swamp white oak (*Q. platanoides*), scales on stem below leaf, early and late, fully formed leaf. Photographed May 1, 1917, by Colburn.

coming smooth, margin of leaf undulate with a few hairs. On May 10 the height of this seedling was from six and one-half to eight and one-half inches.

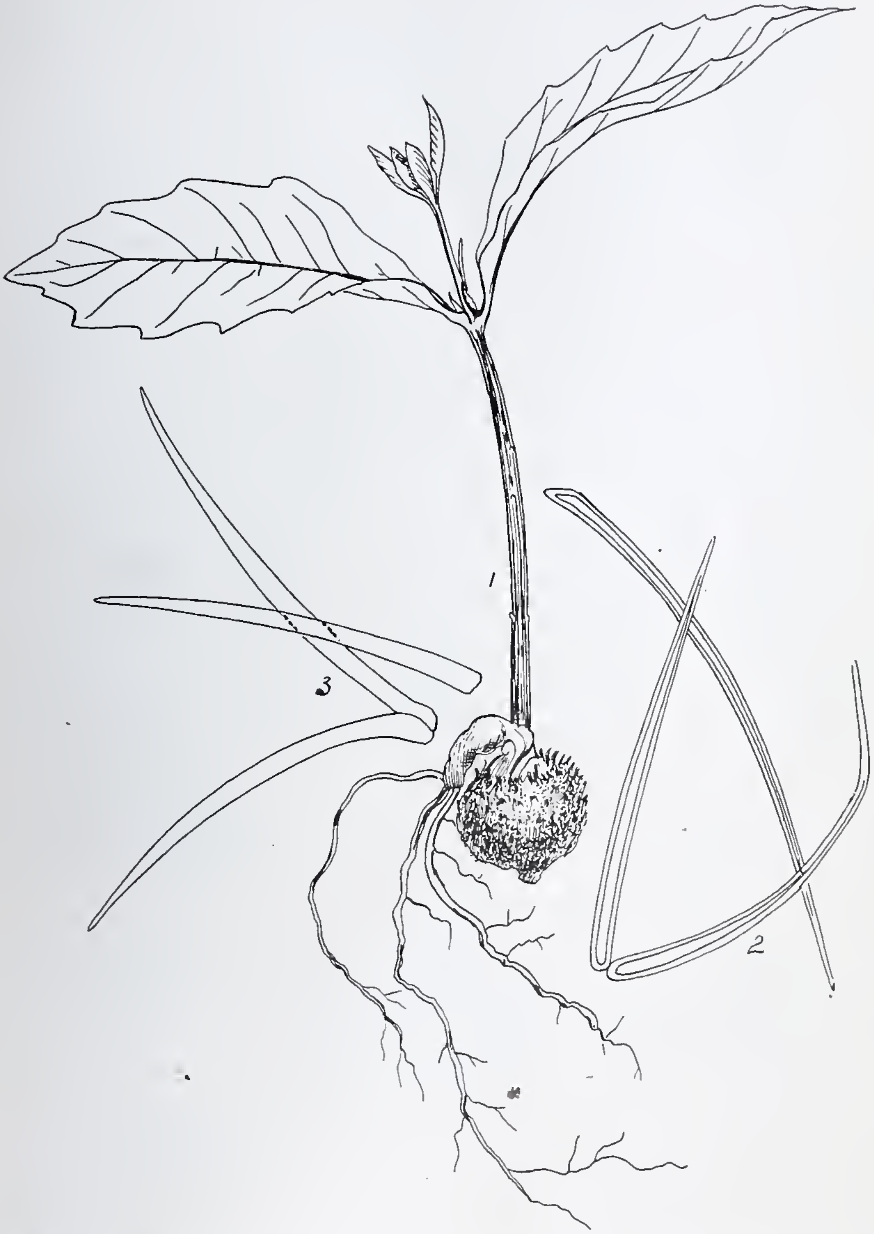

Fig. 72.—The bur oak (*Quercus macrocarpa*); 1, germinating acorn in cup; 2, trichomes of stem; 3, trichomes of leaf. Drawn by C. M. King.

Bur Oak (*Quercus macrocarpa* Michx.). Acorns planted on October 2 in sandy humus covered with sphagnum moss were kept moist. Germination did not occur until April. However all the acorns did not germinate at one time. The total germination was 65 per cent. In germination the strong hypocotyl pushed out from the apical end, soon becoming woody and dark in color, showing lenticels, trichomes singly or in some instances in groups of two, long pointed, straight or curved, cell walls thick, white, cell contents brown. The first leaves scalelike, pubescent, becoming successively larger, petioles and young leaves pubescent on both surfaces, the larger leaves penni-nerved, of firm texture, margin scalloped with simple hairs, trichomes on upper surface and on midrib, thick walled, light colored, long pointed, singly or in groups of two or three, cell-walls light colored, cell contents brown, leaves of lower surface pale in color, similar to the upper, pubescent on midrib and veins, also with scattered hairs. On May 10 seedlings of the oak were from four and one-half to eight inches in height.

Red Oak (*Quercus rubra* L.). Acorns from St. Charles, Missouri, were planted on October 21 and from Ames, Iowa, on September 24, in sandy humus covered with sphagnum moss and kept moist. Germination did not occur until March. They did not, however, all germinate at the same time, but continued to germinate until April 23. Thirty-nine and four-tenths per cent of the St. Charles acorns had germinated. Of the Ames material 34.96 per cent germinated. The hypocotyl pushed its way out through the apical end, at once producing a strong woody hypocotyl, the plumule coming out near the basal part. The lower part of the stem is somewhat pubescent. The trichomes slender, pointed, colorless, simple.

The scales became successively larger, leaves penni-nerved, bright green above, lower surface paler in color, midrib above in some cases reddish, in others greenish. Pubescence on midrib and veins on lower surface sparse, very young leaves pubescent above and below. The trichomes on lower surface clustered in groups of generally four or more cells, with stellate appearance, usually straight, shorter than in the white oak group, pointed, walls colorless, contents of cell brown, upper surface with few trichomes. Teeth widely separated, each tipped with a prominent bristle. On May 10 the seedlings averaged five and one-fourth inches in height.

Acorns of *Q. rubra* gathered in the fall and left in the laboratory all winter were placed in damp moss in May. At the close

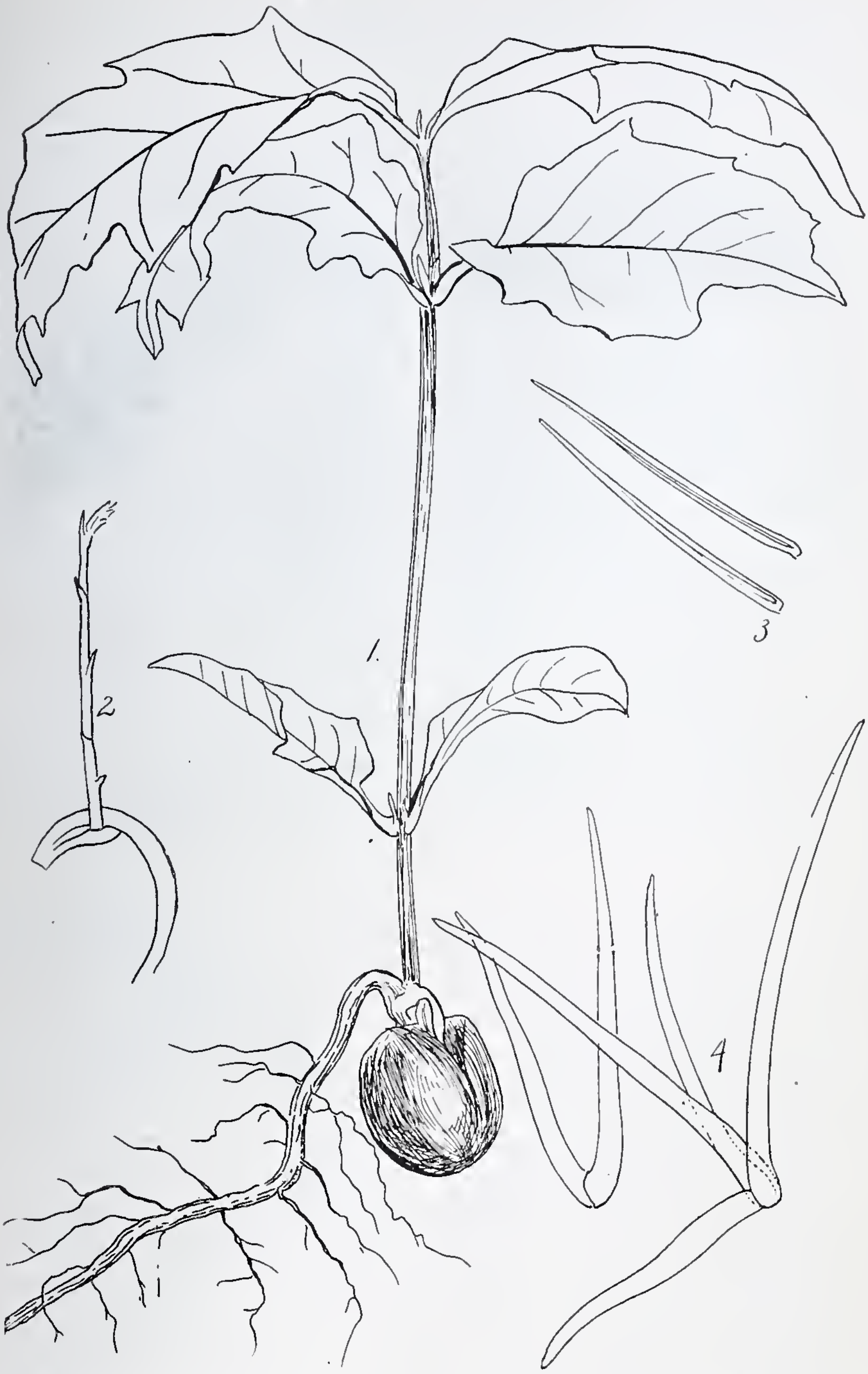

Fig. 73.—1. Germination of red oak (*Quercus rubra*), leaves and stipules; 2, as the stem emerges from the ground; 3, trichomes from stem; 4, trichomes from leaf. Drawn by C. M. King.

of three weeks' time, none had germinated. The acorns were sound when planted, upon being cut open the acorns were found to be brown, indicating that life was destroyed during the long period of drying out.

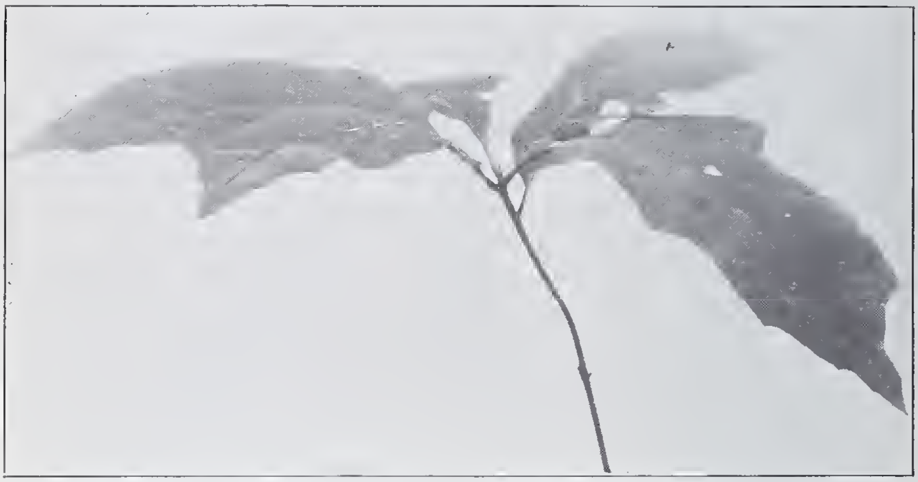

Fig. 74.—Young red oak (*Q. rubra*) stipules, scales below and fully formed leaves. Photographed May 1, 1917, by Colburn.

Quercitron Oak (*Quercus velutina* Lam.). Acorns gathered on September 23 were planted in greenhouse on September 24, in sandy humus, covered with sphagnum. The acorns did not germinate until April. Although only sound acorns were planted the germination was only 25 per cent.

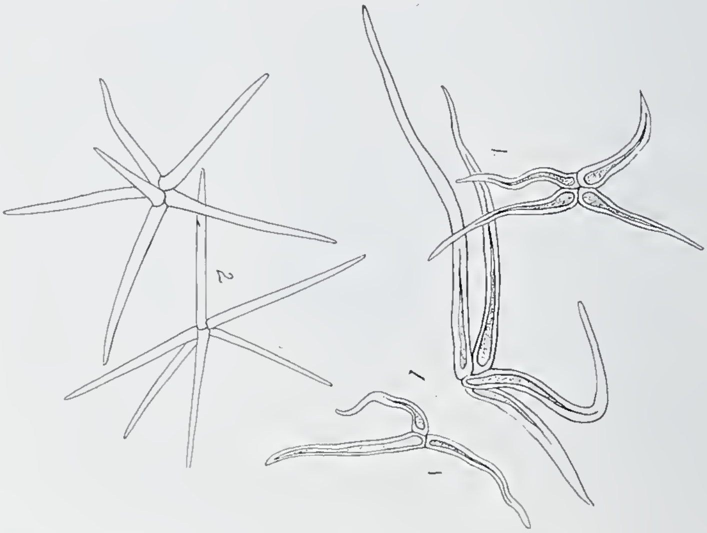

Fig. 75.—Trichomes of *Quercus velutina*; 1, from stem; 2, from leaf Drawn by C. M. King.

The strong hypocotyl pushed out from the apical end and soon became woody. The plumule emerged near the basal portion of the hypocotyl. The young stem was covered with yellowish hairs, trichomes occurring singly or in clusters, or more correctly, a group of trichomes formed small cells at the base, giving it a stellate appearance, the individual hairs variable in length, thick colorless walls and brown contents, the first leaves of small pubescent scales, leaves becoming successively larger, penni-nerved, pubescent on midrib, veins and scattered, trichomes of two kinds on lower surface of leaf, the clustered trichomes with stellate appearance numerous, five or more cells with small basal cells; straight or slightly curved, wall thick, colorless, the simple trichomes woolly, brownish in color, upper surface of leaf similar but less pubescent, the veins conspicuously anastomosing, young buds in seedlings conspicuously pubescent, wholly unlike the red and shingle oaks. On May 10 these oak seedlings were from two to three and one-half inches high.

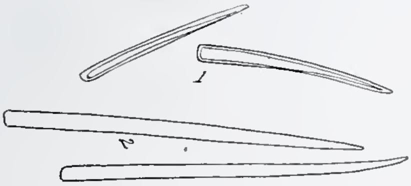

Fig. 76.—Trichomes of *Quercus imbricaria;* 1, from stem; 2, from leaf. Drawn by C. M. King.

Shingle Oak (*Quercus imbricaria* Michx.). Seeds planted in sandy humus, kept moist by placing sphagnum moss on the soil. Seeds germinated in March. Produced strong hypocotyl, young stem smooth at first and lower leaves scalelike, upper successively larger, elongated penni-nerved margin with a few broad dentations; first leaves not dentate, marginal bristles short, midrib much more prominent than the lateral, margin wavy smooth, upper surface nearly smooth, except a few hairs on midrib, trichomes occur singly or in fewer cases in groups of two or three, long pointed, straight or slightly curved, cell-wall thick, light colored, cell contents brown, midrib or lower surface with a few scattered hairs. On May 10 this oak seedling was six inches in height.

Water Oak (*Quercus aquatica* Walt.). Acorns came from Wm. Diehl of Clemson College, South Carolina. They were placed in damp sphagnum moss immediately upon arrival here, about November first. They were left for a few weeks but no changes occurred. They were then transferred to sandy humus, covered with sphagnum and placed in the greenhouse where they were watered every day. The seeds did not germinate until April 18, when the plumule appeared above the ground. A second seed pushed through the soil on April 24. The hypocotyl

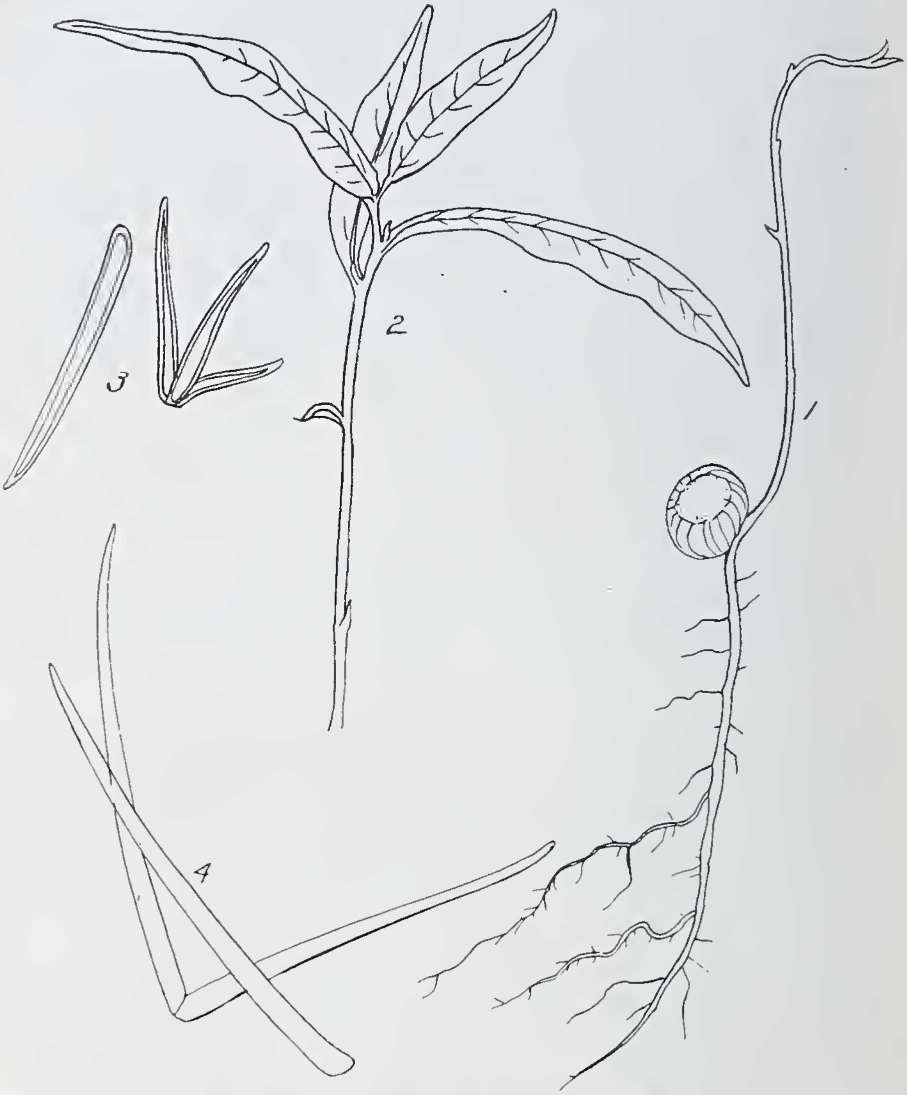

Fig. 77.—1. Germinating acorn of *Quercus aquatica*. 2. A little later stage, scales below. 3. Trichomes from stem. 4. Trichomes from leaf. Drawn by C. M. King.

pushed its way through the apical end of the acorn. It grew rapidly in length, soon becoming woody and brownish in color, with lateral roots, the plumule coming from near the base. Stem slightly pubescent, trichomes in most plants singly or in

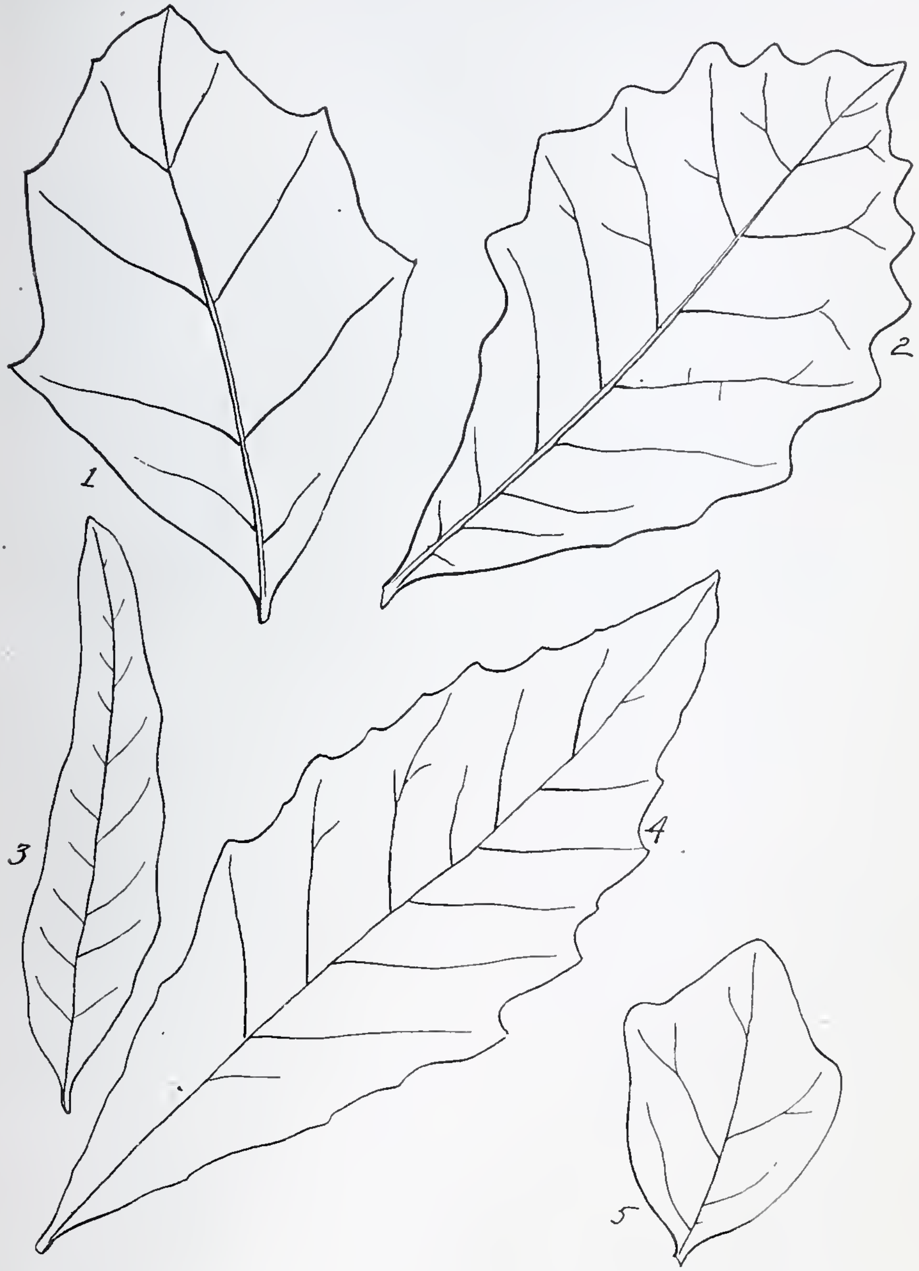

Fig. 78.—Young leaves of oaks: 1, *Quercus velutina;* 2, *Quercus macrocarpa;* 3, *Quercus aquatica;* 4, *Quercus platanoides;* 5, *Quercus stellata.* Drawn by C. M. King.

some cases of two or three cells, long pointed, straight or slightly curved, cell-walls thick, contents brown. First leaves of scales reddish, becoming green; the scale pointed, pubescent, larger leaves on midrib and pubescent on margin with

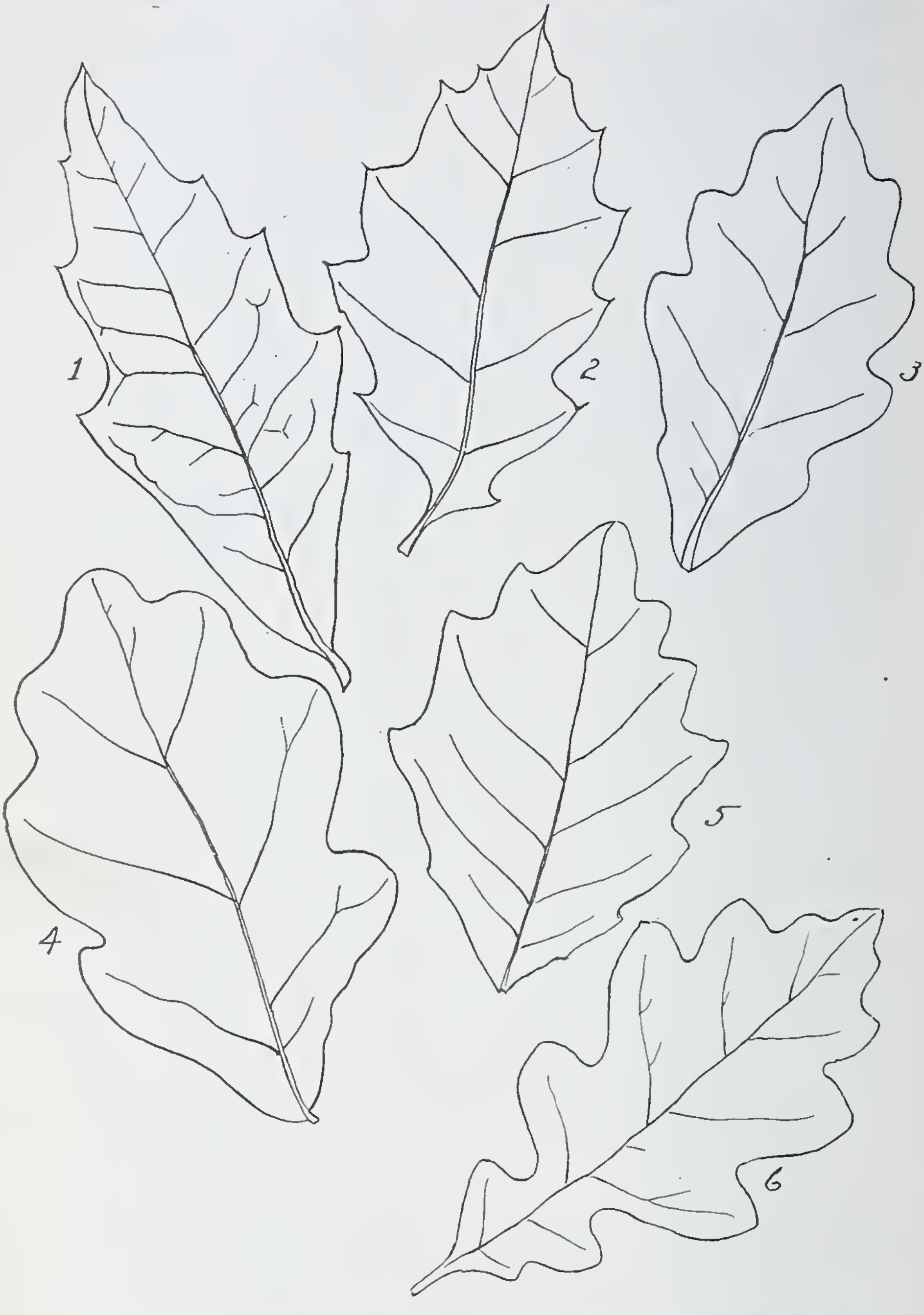

Fig. 79.—Young leaves of oaks: 1, *Quercus imbricaria;* 2, *Quercus rubra;* 3, *Quercus Robur* var. *pedunculata;* 4, *Quercus alba;* 5, *Quercus acuminata;* 6, *Quercus lobata.* Drawn by C. M. King.

stipules oblique, small reddish petiole slightly pubescent, prominently penni-nerved, veins anastomosing, margin wavy, entire, slightly revolute, midrib below and above smooth. On May 10 this seedling was three and one-half inches in height.

REFERENCES.

Ward, H. Marshall, The Oaks, 1892.

Tubeuf, K. Samen, Früchte u Keimlinge, Berlin, 1891.

Engelmann, G., Acorns and their Germination: Trans. Acad. Sci., St. Louis, *4,* 190-192, 1880.

Meehan, T. L., On the Cotyledons of Quercus: Proc. Acad. Natl. Sci. Philadelphia, 155, 1871.

——————— and Mazyck, W., Germination in Acorns: Ibid, 29, 1880.

Stenzel, Zwei Nachträge sur Keimung der Eichel: Jahresb. Schles Gesell, veterland, Kultur, *54,* 105, Breslau, 1877.

——————— Samenformen bei der Eiche: Biblioth, Botan., Heft 21, Cassel, 1890.

Tubeuf, Die Buchenkeimlinge von Sommer 1889: Bot. Centralblatt, *41,* 374, 1890.